L A N D S A T   Data Continuity Mission

LDCM

DRAFT

Space Segment Requirements Document

Landsat Data Continuity Mission

June 14, 2006

Revision - Draft

CM FOREWORD

This document is a Landsat Data Continuity Mission (LDCM) Project Configuration Management (CM)-controlled document. Changes to this document require prior approval of the applicable Configuration Control Board (CCB) Chairperson or designee. Proposed changes shall be submitted to the LDCM CM Office (CMO), along with supportive material justifying the proposed change. Changes to this document will be made by complete revision.

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Document Revision History

This document is controlled by the LDCM Project Management. Changes require approval of the LDCM Project Manager, LDCM Observatory Manager, and the LDCM Mission Assurance Manager. Proposed changes shall be submitted to LDCM Systems Engineering Manager.

RELEASE	DATE	BY	DESCRIPTION
–			Initial Version

List of TBD's/TBC's/TBR's

This document contains information that is complete as possible. Items that are not yet defined are annotated with TBD (To Be Determined). Where final numerical values or data are not available, best estimates are given and annotated TBC (To Be Confirmed). If there is an inconsistency between two requirements then the best estimate is given and annotated with a TBR (To Be Resolved). The following table summarizes the TBD/TBC/TBR items in the document and supplements the revision history.

ITEM	REFERENCE	DESCRIPTION
		Data not supplied

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1 Introduction

1.1 Scope

The Space Segment Requirements Document (SSRD) document establishes the Level 3procurement requirements for the Landsat Data Continuity Mission (LDCM). Also include is an allocation matrix of the Space Segment level requirements to the appropriate subsystems.

1.2 Document Organization

This document is organized into four general areas. Section 1 provides scope, general organization of the document and identifies applicable and reference documents. Section 2 provides a mission definition with an overview of the LDCM and describes its science objectives and mission segments. In addition the user community and external interfaces are identified. Section 3 provides the definitions and terminology that is used within this document. Sections 4 through 14 provide the level 3 requirements. Section 15 provides for the allocations traceability and Section 16 provides for the Verification Cross Reference Matrix.

1.3 Change Control

The approved SSRD will be placed under configuration control. Any proposed changes to the SSRD will require Configuration Control Board approval as per the Systems Engineering Management Plan. Requests for changes to the SSRD will be submitted directly to the LDCM Configuration Control Manager, who will coordinate the appropriate review process. Revisions to the SSRD will be made through a formal change process. The Configuration Control Manager will route change requests to the Mission Systems Manager, who will obtain the necessary agreements from project management, scientists, and engineers before release as the official version. Changes are approved and signed by those on the signature sheet. NASA Goddard Space Flight Center is responsible for revisions and will maintain documentation for all change requests.

1.4 Mission Requirements Flow

The general structure of the LDCM Program requirements is shown in Figure 1-1. The flow down represented in this figure identifies which organization controls a set of requirements and who has the authority to change those requirements.

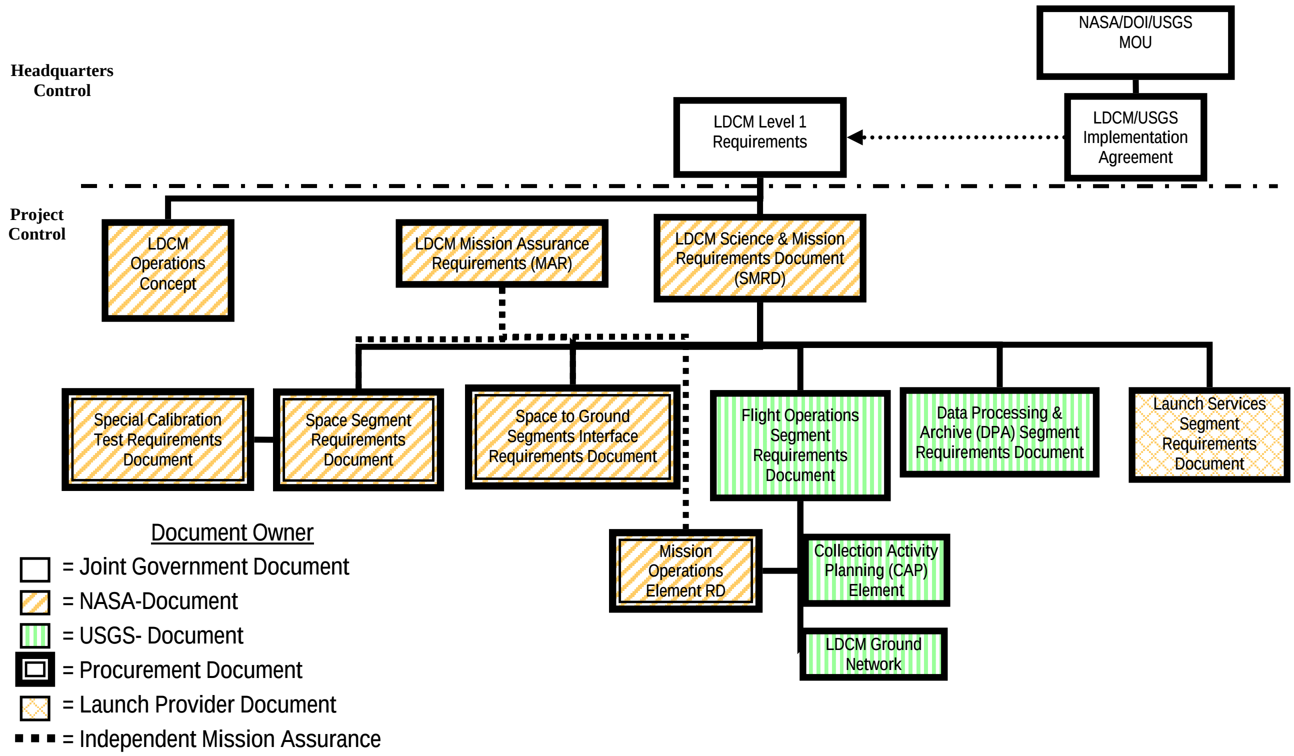

Figure 1-1 LDCM Requirements Flow

2 Applicable Documents

2.1 LDCM Project Level Documents

The SSRD is consistent with, and responsive to, the following documents of the exact issue and revision shown. Unless otherwise stated in this document, all inconsistencies in this SSRD will be resolved in the following order:

1. LDCM Contract
2. LDCM SOW
3. LDCM Mission Assurance Requirements
4. Space Segment Requirement Document (SSRD, Level 3) and Mission Operations Element Requirements Document (MOERD, Level 3)
5. LDCM Space to Ground Segments Interface Requirements Document (IRD)

GSFC Document Number	Revision/ Release Date	Document Title
427-xx-xx		Level 1 Requirements for the LDCM Mission
427-xx-xx		Science and Mission Requirements Document
427-xx-xx		LDCM Lexicon
427-xx-xx		LDCM Operations Concept Document
427-xx-xx		Space to Ground Segments IRD
427-xx-xx		Statement of Work
427-xx-xx		Mission Assurance Requirements
427-xx-xx	Rev. -, June X, 2006	Tailored GSFC STD-1000 Rules for the Design, Development, Verification and Operation of Flight Systems (GOLD Book)
427-xx-xx	Rev. -, June X, 2006	LDCM Tailored GSFC GEVS [TBD]
427-xx-xx		Special Calibration Test Requirements (SCTR)
White paper		LDCM World Reference System-2

Table 2.1-1 LDCM Project Level Documentation

2.2 Government Documents

Compliance with the following US Government documents is required:

Document Number	Revision/ Release Date	Document Title
NASA STD-5005	Rev. B, Sept. 5, 2003	Ground Support Equipment
NPD 8710.3	Rev. B, April 28, 2004	NASA Policy for Limiting Orbital Debris Generation
NSS 1740.14	August 1995	NASA Safety Standard, Guidelines and Assessment Procedures for Limiting Orbital Debris
NPR 2810.1	August 26, 1999	NASA Policy Guideline, Security of Information Technology
USAF	July 1, 2004	Air Force Space Command Manual 91-710 Range Safety User Requirements

Table 2.2-1 Government Documents

2.3 Reference Documentation

The SSRD is consistent with the following documents. If the SSRD conflicts with the any of these listed documents, the SSRD takes precedence.

Document Number	Revision/ Release Date	Document Title
CCSDS 122.0–B–1		Recommendation for Space Data Systems Standards. Lossless Data Compression. CCSDS Recommendation, Blue Book, May 1997.
CCSDS 202.0–B–3	June 2001	Recommendation for Space Data Systems Standards. Telecommand, Part 2: Data Routing Service. CCSDS Recommendation, Blue Book
CCSDS 232.1–B–1	September 2003	Recommendation for Space Data Systems Standards. Communications Operations Procedure-1. Blue Book. Issue 1.
CCSDS 701.0–B–3		Recommendation for Space Data Systems Standards. Advanced Orbiting Systems, Networks, and Data Links: Architectural Specification. CCSDS Recommendation, Blue Book, June 2001.
42 U. S. C., 4321 et seq. NEP	Sept. 13, 1982	National Environmental Policy Act of 1969
KNPR 8715.3		KSC Safety Requirements
STDN 101.2	Rev. 7 /Nov. 1995	GSFC Space Network (SN) Users' Guide

Table 2.3-1 Reference Documents and Standards

3 Definitions

3.1 Observatory Modes

This document uses the following definition of observatory modes. Though the LDCM contractor is not required to use these same definitions; a mapping of the contractor's observatory modes to these is required.

Ground Based Storage Mode, a non-operational mode, with minimal support for up to 30 days at a time. This mode may last for as much as 180 days and may be entered into at either the contractor's or government provided facilities.

Launch Mode for integration and testing with the launch vehicle and for the launch phase through separation. This is a non-nominal operational mode.

Survival Mode provides a maximum power positive attitude and an observatory configuration that maintains the observatory in a power safe, thermally safe and optically safe configuration for an indefinite period of time requiring no ground contact. This is a non-nominal operational mode.

Safe Hold Mode that provides for a coarse nadir earth point attitude and an observatory configuration that provides maximum ability for check-out, and diagnostics in a power safe, thermally safe and optically safe configuration for an indefinite period of time. This is a nominal operational mode.

Mission Mode that provides for a fine earth point achieving mission attitude requirements which supports continuous operations. This is a nominal operational mode.

Calibration Mode that provides for lunar, celestial and earth's limb pointing capability. This is a nominal operational mode.

Propulsion Mode that provides for orbit and inclination adjustments. This is a nominal operational mode.

Off-nadir Point Mode that provides for the observatory to point one WRS-2 swath left or right of the current WRS-2 grid. This is a nominal operational mode.

3.2 Mission Phases

Storage Phase begins after completion of the LDCM Observatory environmental test campaign and ends with the delivery of the observatory for final ground processing.

Pre-Launch Phase begins after delivery of the LDCM Observatory to the launch site and ends at liftoff. This phase is divided into two sub-phases, the Observatory processing at the launch site before integration to the launch vehicle and the Observatory processing at the launch pad.

Launch and Early Orbit Phase begins at lift-off and ends after the LDCM Observatory has been commanded into a Safe Hold Mode and normal operations of the power and attitude control subsystems have been verified.

Observatory Commissioning Phase begins at the completion of the Launch and Early Orbit Phase and ends with acceptance by the NASA of the LDCM Observatory for the Operational Phase of the LDCM. During the Commissioning Phase all on-orbit functional requirements must be demonstrated.

Operational Phase begins at the completion of the Observatory Commissioning Phase and extends through the life of the LDCM Observatory. End of mission life for the LDCM Observatory is to be assessed by a DOI/USGS convened review board which ensures that the observatory decommission requirements can be meet.

Decommissioning Phase is defined as the period of time after the end of the Operational Phase and extends through the implementation of the de-orbit maneuvers and de-energize the observatory in compliance with the NSS 1740.14.

3.3 Coordinate System

The LDCM Observatory body reference coordinate system is defined as a right-hand, orthogonal, body fixed, XYZ coordinate system with the +Z axis aligned with the image sensor field of view. The origin is located at the observatory to launch vehicle interface plane and in the physical center of the observatory.

4 Mission

4.1 General

The LDCM Observatory shall be capable of acquiring image sensor data at any point throughout the orbit.
Rationale: Take an image anywhere within the orbit.

The LDCM Observatory shall be capable of acquiring the image sensor data equivalent to 400 WRS-2 scenes plus the necessary calibration data per 24 hour period.
Rationale: The LDCM Observatory will be capable of acquiring, buffering and successfully transmitting sensor image data equivalent to 400 WRS-2 scenes per day plus any necessary calibration data. Calibration data may include lunar, solar, earth limb imaging results.

The LDCM Observatory shall transfer all mission data to the ground within 12 hours of observation.

The LDCM Observatory shall be capable of acquiring up to 5 priority scenes per day.
Rationale: For rapidly changing conditions on the earth LDCM will be able to image either WRS-2 scenes or off-nadir scenes and mark them as priority

The LDCM Observatory shall transfer priority scenes to the ground within 3 [TBC] hours of observation.

The LDCM Observatory shall be capable of acquiring image intervals up to one WRS-2 path located on either side of the current nadir, WRS-2 path.
Rationale: This acquisition is in lieu of an equivalent amount of nadir WRS-2 path image acquisition.

The LDCM Observatory shall be capable of acquiring up to 5 off-nadir image intervals per day.

The LDCM Observatory shall be capable of acquiring up to 38-night [TBC] WRS-2 Scenes during any 24-hour period.

The LDCM Observatory shall be capable of being commanded by the ground into any operational mode.

The LDCM Observatory shall be designed not to cause orbital debris as per NPD 8710.3.
Rationale: The NPD provides guidelines for minimizing orbital debris. It also invokes NASA Safety Standard NSS 1740.14 for assessing debris and mission survivability.

The LDCM Observatory shall be capable of using the NASA Space Network Support (TDRSS) for command and telemetry.

The LDCM Observatory shall be capable of using the NASA Ground Network Support (GN) for command and telemetry.

The LDCM Observatory shall use the LDCM Ground Network for wideband data reception.

The LDCM Observatory shall use the LDCM Ground Network for command and telemetry.

The LDCM Observatory shall be capable of transmitting mission data to International Ground Stations in real time.
Rationale: IC's are provided data directly from the observatory to the IC's station

The LDCM shall use the Système International (SI) units for defining interfaces; the usage of any other unit(s) other than the SI shall be clearly communicated and documented.

4.2 Mission Lifetime

The LDCM Observatory shall be designed for 5 years of mission life beginning at the NASA Acceptance of the Observatory.

The LDCM Observatory shall be designed for an overall Probability of Mission Success of 0.80 [TBC] or better at the end of design mission life.

The LDCM Observatory shall have a propellant loading sufficient to complete orbit raising, 10 years of nominal mission operations and decommissioning.

4.3 Mission Phases

4.3.1 Storage Phase

The LDCM Observatory shall be capable of being placed in a low maintenance state, ground based storage mode for 30 day periods for up to 180 days.

The LDCM Observatory shall be capable of being placed in physical storage after assembly, integration and environmental tests in such a way so as to prevent degradation of its components and to allow for the rapid transition to the Pre-Launch Phase.

4.3.2 Pre-Launch Phase

The LDCM Observatory shall be designed for a launch from Vandenberg AFB.

The LDCM Observatory and Ground Support Equipment used at the launch site shall comply with the US Air Forces Space Command Manual 91-710 Range Safety User Requirements, dated July 1, 2004.

The LDCM Observatory shall make available real-time and stored housekeeping telemetry while at the launch pad.

The LDCM Observatory shall interface with NASA/KSC provided launch vehicle as defined in the Delta II [TBC] to LDCM Mission Interface Control Document.

The LDCM Observatory shall be designed to monitor the status of the propulsion system while the observatory is powered off through the launch vehicle interface umbilical.

The LDCM Observatory shall be designed to monitor the status of the electrical storage system while the observatory is powered off through the launch vehicle interface umbilical.

The LDCM Observatory shall be capable of performing aliveness, functional and limited performance tests while mated to the launch vehicle.

4.3.3 Launch and Early Orbit Phase

The LDCM Observatory shall transmit real-time, narrowband, observatory housekeeping telemetry during launch ascent starting after launch vehicle fairing separation.

The LDCM Observatory shall receive real-time, command telemetry during launch ascent starting after launch vehicle fairing separation.

The LDCM Observatory shall be powered on for launch.

The LDCM Observatory shall transmit real-time observatory housekeeping telemetry during the launch phase following launch vehicle fairing separation.

4.3.4 Observatory Commissioning Phase

Reserved

4.3.5 Operational Phase

Reserved

4.3.6 Observatory Decommissioning Phase

The LDCM Observatory shall ensure that onboard energy sources (mechanical, electrical and chemical) are depleted during this mission phase.
Rationale: Thus minimizing potential for future orbital debris

The LDCM Observatory shall complete a de-orbit maneuver sufficient to ensure that the LDCM Observatory enters the Earth's atmosphere in compliance with NASA Safety Standard (NSS) 1740.14.

4.4 Orbits

4.4.1 General

The LDCM Observatory shall be capable of performing drag makeup maneuvers.

The LDCM Observatory shall be capable of performing inclination maneuvers.

4.4.2 Injection Orbit

The LDCM Observatory shall achieve the operational orbit after separation from the launch vehicle at the following injection orbit:

- Semi-Major Axis: 7063 km [TBC]
- Mean Eccentricity: 0.000 [TBC]
- Mean Inclination: 98.22 deg [TBC]
- Mean Local Time (MLT) of the Descending Node: 1000 [TBC]

The LDCM Observatory shall achieve the operational mission orbit when the following dispersions are applied to the injection orbit:

- Perigee Altitude error: -25 km, +9.3 km
- Apogee Altitude error: -9.3 km, +9.3 km
- Inclination error: +/- 0.05 deg
- Injection Node MLT error: +/- 2.5 minutes

The LDCM Observatory shall have a daily launch window of 5 minutes [TBC].

The LDCM Observatory shall have a launch readiness capability once every 24 hours.

4.4.3 Operational Orbit

The LDCM Observatory shall be capable of imaging any area on the earth surface at least once every 16 days with the exception of 817 km radius circles centered at the North Pole and South Pole.

The LDCM Observatory shall operate in a sun-synchronous, near circular, frozen orbit described as follows:

- Equatorial Altitude: 705 km
- Semi-Major Axis: [TBD]
- Eccentricity: 0.00125 [TBC]
- Mean Local Time of the Descending Node: 10:00 a.m.
- Ground Track: WRS-2 Grid
- Repeat Cycle: 16-days

The LDCM Observatory shall achieve the operational mission orbit when the following dispersions are applied to the operational orbit:

- eccentricity: +/- 0.0005
- Inclination: +/- 0.001 deg
- MLT of the descending node: +/- 7.5 [TBC] minutes
- Ground Track Error: +/- 5 km cross track at the descending node

The LDCM Observatory shall be capable of maintaining the Operational Orbit for the life of the mission.

4.4.4 Disposal Orbit

The LDCM Observatory shall complete a de-orbit maneuver sufficient to ensure that the LDCM Observatory enters the Earth’s atmosphere within 25 years of decommissioning Rationale: See Reference NSS 1740.14).

4.5 Redundancy Requirements

The LDCM Observatory shall be designed such that no single credible failure permanently precludes the LDCM Observatory from completing the design mission life.

The LDCM Observatory shall be capable of redefining the prime and backup unit for redundant systems from the ground.

Rationale: Be able to switch back and forth between prime and backup units through ground commands

The LDCM Observatory shall provide indication of which unit is operating in housekeeping data to the ground for redundant systems.

4.6 Autonomy

4.6.1 Autonomous Features

The LDCM Observatory shall be capable of autonomously transitioning from the Mission, Calibration, Propulsion and Off-nadir Point Modes into the Safe Hold Mode.

The LDCM Observatory shall be capable of autonomously transitioning from the Safe Hold Mode to the Survival Mode.

The LDCM Observatory shall not autonomously transition out of the Survival Mode.

The LDCM Observatory shall not autonomously transition from the Safe Hold Mode into the Mission, Calibration, Propulsion or Off-nadir Point Modes.

The LDCM Observatory shall be capable of operating nominally for 72 [TBR] hours autonomously.

The LDCM Observatory shall have the ability to autonomously perform reconfiguration of redundant components.

The LDCM Observatory shall not autonomously switch control to a failed redundant component.

The LDCM Observatory shall be capable of programming the downlink sequence by ground command for the full time span of autonomous operations.

The LDCM Observatory shall be capable of initiating a stored command in response to pre-defined conditions.

The LDCM Observatory shall be capable of over-riding autonomous functions via ground command.

The LDCM Observatory shall report autonomous reconfigurations in normal telemetry.

The LDCM Observatory shall monitor component, subsystem, and housekeeping data.

4.6.2 Failure Detection and Protection

The LDCM Observatory shall automatically detect out of limit conditions for hardware and software.

The LDCM Observatory shall provide the capability to run on-board diagnostics and report the results in telemetry.

The LDCM Observatory shall accept ground commands to run on-board diagnostics and report the results in telemetry.
Rationale: Flexibility is necessary to support debugging conditions that may not be known until after launch.

The LDCM Observatory shall automatically place itself in a safe operational mode based on detected out of limit conditions.

The LDCM Observatory shall perform Power On Self Test (POST) diagnostics at power-on.

The LDCM Observatory shall monitor and report Power On Self Test (POST) results in the housekeeping telemetry.

The LDCM Observatory shall monitor and reject invalid commands.

The LDCM Observatory shall report false commands in housekeeping telemetry.

The LDCM Observatory shall attempt a soft recovery of a subsystem element before power cycling it.

The LDCM Observatory shall safe itself in the event of an anomaly.

The LDCM Observatory shall implement independent time-based monitoring circuits.

4.7 Availability

The LDCM Observatory shall be available for acquiring image sensor data at least 93% [TBC] of the time during a WRS-2 Observation Period.

4.8 Ground Support Equipment

The LDCM Ground Support Equipment (GSE) shall be in compliance with NASA-STD-5005 Ground Support Equipment.

The LDCM GSE shall provide necessary stimulus and simulation means to support the attitude and orbit control system testing.

The LDCM GSE shall provide mission operational simulation of the solar array power generation capability.

The LDCM GSE shall be capable of battery conditioning, charging, trickle charge and verification.

The LDCM GSE shall be capable of providing power to the Observatory with flight batteries installed.

The LDCM GSE shall be capable of providing power to the Observatory without flight batteries installed.

The LDCM GSE shall provide the necessary RF front ends and check-out capabilities to verify the Observatory functionality.

The LDCM GSE shall provide means for status verification and leak detection of the propulsion subsystem.

The LDCM GSE shall provide the capability to monitor the status of the Service Platform power switches.

4.9 Observatory Simulator

The LDCM Observatory Simulator shall be capable of operating independently from the LDCM Flight Operations Segment.

The LDCM Observatory Simulator shall be capable of integration into the LDCM Flight Operations Segment.

The LDCM Observatory Simulator shall simulate the operations of the command and data handling system.

The LDCM Observatory Simulator shall simulate the operations of the attitude and orbital control system.

The LDCM Observatory Simulator shall simulate the operations of the mass storage system.

The LDCM Observatory Simulator shall simulate the operations of the power system.

The LDCM Observatory Simulator shall simulate the operations of the image sensor(s).

The LDCM Observatory Simulator shall simulate the interface between the Mission Operations Element (MOE) and the observatory telecommunications system.
Rationale: So that the observatory simulator can talk to the MOE there needs to be a ground station interface simulator. This requirement addresses the fact that the ground RF is not present for the simulator.

The LDCM Observatory Simulator shall be capable of simulating all observatory operational modes and mode transitions.

** The following requirements are to establish a minimum simulation capability. They may produce unintended results by limiting what the contractor wants to bring to the table. **

The LDCM Observatory Simulator shall validate commands, table updates and flight software modifications.

The LDCM Observatory Simulator shall receive commands in any valid format and data rate.

The LDCM Observatory Simulator shall be capable of receiving, processing and executing flight software updates.

The LDCM Observatory Simulator shall be capable of generating a telemetry stream with representative observatory data in all valid formats and data rates.

The LDCM Observatory Simulator shall simulate the response characteristics of failed observatory subsystems.

The LDCM Observatory Simulator shall respond to real-time operator changes in the configuration of the simulated observatory.

The LDCM Observatory Simulator shall accept inputs from the user to set and change simulation variables.

The LDCM Observatory Simulator shall accept inputs from the user to set and synchronize simulation time with observatory clock time and ground system time.

The LDCM Observatory Simulator shall be capable of running a previous executed simulation.

5 Imagery Requirements

The imaging section of the SSRD was released earlier to industry for comments. Section 5.0 will be integrated into a final DRAFT release of this document following integration of comments from industry.

5.1 General

5.2 Ancillary Data

5.3 Data Processing Algorithms

5.4 Spectral Bands

5.5 Spatial Data Sampling Intervals

5.6 Radiometry

5.7 LDCM Geometric Precision, Geolocation, and Cartographic Registration

5.8 LDCM Thermal Band Option

5.9 In-Flight Calibration

The image sensor shall have on-board calibration systems that provide sufficient data with precision and accuracy to meet the calibration and stability requirements of the image sensor as described in this document.

5.9.1 Reflective Band Calibration Sources

Sources for the in-flight calibration shall include celestial objects including both the sun and the moon, and on-board sources such as lamps.

5.9.2 Reflective Band On-board Calibration Systems

The calibration systems shall at a minimum include:

a.) A full aperture full system space-grade Spectralon solar diffuser with the capability to assess the diffuser deployment orientation stability with time. The solar diffuser shall be designed to operate at a solar zenith angle of no greater than 60° and a view zenith angle of no greater than 45° (TBR). The in-flight calibration system shall maintain absolute radiometric accuracy as stated for the image sensor or better.

b.) A lamp calibration source with at least three selectable lamps, each of which illuminates all detectors. The lamps shall be operable in constant irradiance and constant current modes. This calibration source shall have at a minimum an independent total optical power output monitor.

c.) A device by which the dark signal of all the detectors can be monitored without violation of the image sensor operations

d.) Permanently masked dark detectors on each end of each detector array in each band to generate sufficient data to track bias stability during daylight acquisitions for each band

e.) A device by which the linearity of the image sensor with respect to radiance can be characterized on orbit

f.) A source designed to be stable between prelaunch and on orbit environments and throughout launch. This source shall be exercised prelaunch and postlaunch to test the transfer to orbit stability of the image sensor

5.9.3 Thermal Calibration Systems

a) A full aperture, full system calibration shall be available for the thermal band option.

6 Structural and Mechanical Systems

The LDCM Observatory structure shall be of sufficient strength and stiffness to maintain structural integrity and withstand all ground testing, handling, transportation, launch, and mission orbit environments.

7 Thermal Control

The LDCM Observatory shall be thermally safe for continuous operations in the Survival, Safe Hold and Mission Modes.

The LDCM Observatory shall maintain all subsystems of the observatory within their survival temperature range when the Observatory is in Survival Mode.

The LDCM Observatory shall maintain all subsystems of the Observatory within their operational temperature range when the Observatory is in any operational mode.

The LDCM Observatory shall maintain the imaging sensor thermally stable within its operational temperature range while in the Mission Mode, Calibration Mode and Off-Nadir Point Mode.

The LDCM Observatory thermal control flight software shall be reprogrammable on orbit.

8 Electrical System

The LDCM Observatory shall provide power generation, power control, energy storage and distribution for the observatory.

The LDCM Observatory shall provide load shedding control and battery management for all observatory operational modes.

The LDCM Observatory shall maintain a positive energy balance at the end of every 1 [TBC] orbit.

The LDCM Observatory shall be power positive over each orbit while in the Survival and Safe Hold modes.

The LDCM Observatory shall provide protection against over voltage, under voltage and over current for the observatory.

The LDCM Observatory shall be capable of being powered from Observatory Ground Support Equipment with flight batteries installed.

The LDCM Observatory shall be capable of being powered from Observatory Ground Support Equipment with flight batteries uninstalled.

The LDCM Observatory shall monitor and report switch positions.

The LDCM Observatory shall monitor and report current.

The LDCM Observatory shall monitor and report voltage.

The LDCM Observatory shall provide electrical energy storage for all observatory operational modes.

The LDCM Observatory energy storage device state of charge shall remain above 40% during the design mission life time.

The LDCM Observatory energy storage device state of charge shall remain above 60% for nominal operational modes.

The LDCM Observatory energy storage device state of charge shall remain above 40% for the Maneuver and Propulsion Modes.

The LDCM Observatory shall provide power distribution for selecting, connecting and disconnecting the imaging sensor(s) and selected observatory equipment to the electrical bus.

The LDCM Observatory shall provide short circuit protection or current limitation for all power distribution wiring.

The LDCM Observatory shall route redundant power distributions independently via redundant harness and different connectors.

The LDCM Observatory shall use socket connectors on the power side of an electrical interface.

The LDCM Observatory shall provide a launch vehicle interface connector for power to the observatory.

9 Flight Software

9.1 General

The LDCM Observatory flight software shall be reprogrammable on orbit.

The LDCM Observatory shall be capable of accommodating flight software updates.

The LDCM Observatory shall verify execution of FSW tasks or functions.

The LDCM Observatory flight software shall provide a mechanism to verify the validity of all memory areas.

The LDCM Observatory flight software shall provide a mechanism to detect and correct single bit memory errors.

The LDCM Observatory stored commands shall be unaffected by a flight software upload.

The LDCM Observatory flight software shall be capable of scheduling and prioritizing tasks.

The LDCM Observatory flight software shall store the version of the software onboard.

The LDCM Observatory firmware shall store the internal identifier of the version of the embedded software onboard.

The LDCM Observatory flight software shall maintain a mapping of table name to memory address location.

The LDCM Observatory flight software shall be capable of updating memory table locations through ground command table names.

The LDCM Observatory flight software shall provide the capability to load any location of on-board memory by referencing its physical memory address.

The LDCM Observatory flight software shall be capable of dumping any location in program memory.
Rationale: to support debugging efforts and provide additional telemetry points which may have been unanticipated at development time

The LDCM Observatory flight software memory dump capability shall not disturb normal operations.

9.2 Event Logging

The LDCM Observatory flight software shall time tag events logged in telemetry with an accuracy of 125 [TBC] milliseconds or better.
Rationale: a reported event would likely contain information on the source processor, flight software task or function, severity level, message identifier and informational string that identifies the cause. The event messages capture anomalous events, redundancy management switching of components and important system performance events and warm and cold restarts.

The LDCM Observatory flight software shall be capable of buffering up to 300 [TBC] event messages in a telemetry queue.

9.3 Initialization

The LDCM Observatory shall initialize flight software and begin operations without the need of a ground based command.

The LDCM Observatory flight software shall be capable of a cold restart of the flight software at the processor level.

The LDCM Observatory flight software shall execute a cold restart following a hardware reset.

The LDCM Observatory flight software shall default to a known telemetry configuration following a cold restart.

The LDCM Observatory flight software shall be capable of a warm restart of the flight software at the processor level.

The LDCM Observatory flight software shall execute a warm restart when restarting from a flight software-commanded reset.

The LDCM Observatory flight software shall preserve memory contents following a warm restart.
Rationale: A warm restart preserves command processing statistics, memory tables and command sequences

The LDCM Observatory flight software shall be capable of executing a warm restart from a flight software command.

The LDCM Observatory flight software shall execute a cold restart after a pre-determined number of warm restarts.

9.4 Stored Commands

The LDCM Observatory flight software shall provide stored absolute-time command sequences and stored relative-time command sequences.

The LDCM Observatory flight software stored command sequences shall be modifiable by ground command.

The LDCM Observatory flight software command sequences shall be enabled, disabled, paused, or cancelled by ground command.

The LDCM Observatory flight software shall be capable of dumping stored commands. Rationale: The stored command buffer needs to be read by the FOT, stored command sequence table can be dumped to the ground by a single command.

The LDCM Observatory flight software shall uniquely identify stored command sequences.

The LDCM Observatory flight software shall use the unique command sequence identifier to report the status of each actively executing command sequence in telemetry.

The LDCM Observatory flight software time resolution for stored commands shall be 0.1 seconds [TBC].

The LDCM Observatory flight software shall provide the capability to execute commands with an accuracy of 0.1 seconds [TBC].

The LDCM Observatory flight software shall provide the capability to store multiple time-tagged command sequences.

The LDCM Observatory flight software shall provide the capability to execute time-tagged commands at the time identified with each command in the sequence.

The LDCM Observatory flight software shall have the ability to execute 3 [TBC] time-tagged command sequences concurrently.

The LDCM Observatory flight software absolute-time stored command sequences shall be capable of invoking relative-time stored command sequences.

10 Telecommunications

10.1 General

The LDCM Observatory shall comply with National Telecommunications and Information Administration (NTIA) Spectrum Standards.
Rationale: We need a document number to reference.

The LDCM Observatory shall comply with International Telecommunication Union (ITU) spectrum utilization and sharing requirements.
Rationale: We need a document number to reference.

The LDCM Observatory shall comply with Space Frequency Coordination Group (SFCG) spectrum masks.
Rationale: We need a document number to reference.

The LDCM shall be capable of transmitting a 10^23-1 maximal pseudo noise pattern (TBR) from all transmitters.
Rationale: This is a testability requirement and we do not have a testability section.

10.2 Narrowband

The LDCM Observatory shall be capable of narrowband reception of ground commands while in any operational mode.

The LDCM Observatory shall be capable of narrowband reception of ground commands while in any orientation.

The LDCM Observatory shall be capable of narrowband transmissions in any observatory operational mode.
Rationale: Real-time HK data is needed to monitor and control the observatory even if the observatory is tumbling out of control.

The LDCM Observatory shall be capable of narrowband transmissions in any observatory orientation.

The LDCM Observatory shall be capable of narrowband transmission and reception concurrently.

The LDCM Observatory shall be capable of a narrowband location beep transmission in any observatory operational mode.
Rationale: This provides a signal for aiding tracking the observatory

The LDCM Observatory shall be capable of sending and receiving narrowband transmissions between the observatory and Space Network S-Band system.

10.3 Wideband

The LDCM Observatory shall be capable of downlinking mission data within 12 hours of an observation.

The LDCM Observatory shall provide a downlink capability of at least 2 [TBC] concurrent and distinct downlinks of wideband data.

The LDCM Observatory shall be capable of wideband transmission of real-time mission data when in contact with a ground station.

The LDCM Observatory shall be capable of wideband transmissions with an attitude of 20 [TBC] degrees total angle off the nadir attitude.

The LDCM Observatory shall be capable of continuously and concurrently transmitting real-time mission data to at least three ground stations.

The LDCM Observatory shall provide isolation between adjacent downlink channels of 40 dB [TBC] or better.

The LDCM Observatory shall provide isolation between simultaneous downlink channels to separate ground stations of 40 dB [TBC] or better.

10.3.1 8 GHz DSN Protection

The LDCM Observatory wideband downlink shall not create RF interference with NASA Deep Space Network communications.

The LDCM Observatory wideband downlinks out-of-band emissions shall not exceed -220.9 dBW/Hz.
Rationale: from "DSN 8 GHz RFI Prevention Guideline Draft" protection criteria applicable to the 8400-8450 MHz SRS (space-to-Earth) deep space band in accordance with ITU-R SA.1157.

The X-Band power spectral density at 8400 MHz and above shall be -255 dBW/m²/Hz or lower.
Rationale: DSN protection

10.4 Interfaces

The LDCM Observatory shall use socket connectors on the power side of a communications interface.

The LDCM Observatory shall provide a launch vehicle interface connector for telecommunications to the observatory.

The LDCM Observatory shall provide an interface to GSE RF test receiver antennas during ground testing.
Rationale: Observatory testing requires an all cables / connector out configuration. The RF system should not injure people or other equipment and should be captured by RF "hats".

11 Command & Data Handling

11.1 General

The LDCM Observatory shall be capable of maintaining the health and safe operations of all elements of the observatory without ground support.

The LDCM Observatory shall continuously monitor the health and safety of the observatory.

The LDCM Observatory shall report the health and safety of the observatory.

The LDCM Observatory onboard processors shall be capable of being reset via hardware commands sent from the ground.

The LDCM Observatory shall be capable of resending stored mission data multiple times.
Rationale: in the event the data was not received by the ground.

The LDCM Observatory shall produce a complete set of ancillary data at least once every 4 seconds [TBC] during imaging.

The LDCM Observatory shall time-tag image sensor data with an accuracy of 200 [TBC] microseconds.

The LDCM Observatory shall time tag the ancillary data with an accuracy of 200 [TBC] microseconds.

The LDCM Observatory shall time synchronize the ancillary data with the image sensor data to within 2.4 [TBC] seconds.
Rationale: Ancillary data needs to be transmitted 2.4 [TBC] seconds (2.4 = 60% of time to generate or frame rate of the ancillary data) of the image sensor data so that the IC's will be able to process the image data upon receipt. If the ancillary data is stale, the ICs can not use it.

11.2 Telemetry

The LDCM Observatory shall generate Channel Access Data Units (CADU) for downlink as defined in CCSDS 701.0-B-3.

The LDCM Observatory shall capable of concurrently recording, downlinking real-time, and downlinking stored telemetry.
Rationale: this capability can be selected in any permutation

The LDCM Observatory shall report commands in housekeeping telemetry when received.

The LDCM Observatory shall report commands in housekeeping telemetry when executed.

The LDCM Observatory shall generate and transmit real-time observatory housekeeping data to the ground.
Rationale: Real-time HK data is needed to monitor and control the observatory.

The LDCM Observatory shall be capable of playing back stored housekeeping data while in any operational mode.

The LDCM Observatory shall be capable of processing and storing analog telemetry from the image sensor.

11.3 Command Capability

The LDCM Observatory shall be capable of decrypting command and data uploads using civil encryption coding in compliance with NASA NPR 2810.1, Section 4.11.

The LDCM Observatory shall be capable of enabling or disabling decryption.

The LDCM Observatory shall be capable of source authentication of all received commands.

The LDCM Observatory shall execute only commands that are source authenticated.

The LDCM Observatory shall accept and execute discrete commands in real time only.

The LDCM Observatory shall accept real-time and stored commands.

The LDCM Observatory shall be capable of storing and retrieving commands for delayed execution.

The LDCM Observatory shall be capable of receiving command loads across multiple contacts.

The LDCM Observatory shall be capable of receiving flight software loads across multiple contacts.

The LDCM Observatory shall validate, process, and execute commands and data loads.

The LDCM Observatory shall be capable of executing absolute time commands and relative time sequenced commands.
Rationale: Relative time sequenced commands are a sequence of commands that can be sent from the command storage following a pre-defined sequence.

The LDCM Observatory shall be capable of updating the stored command table.
Rationale: This says reloading or editing the command buffer is covered by one general requirement

The LDCM Observatory shall support Command Operations Procedure-1 as defined in CCSDS 202.0-B-3 and CCSDS 232.1–B–1.

The LDCM Observatory shall be capable of supporting all nominal operations with no more than 20 [TBC] minutes of command uplink every 24 hours.

The LDCM Observatory shall be capable of executing a command at a frequency of at least 1 Hz [TBC].

11.4 Mass Storage

The LDCM Observatory shall be capable of storing observatory health and safety data.

The LDCM Observatory shall identify priority scenes in mass storage.

The LDCM Observatory shall downlink priority scenes before downlink non-priority scenes.

The LDCM Observatory shall overwrite non-priority mission data before overwriting priority mission data.

The LDCM Observatory shall overwrite mission data starting from oldest to youngest.

The LDCM Observatory shall be capable of storing 24 [TBC] hours of wideband data onboard.

The LDCM Observatory shall implement error detection and correction capability to correct single event upsets in mass storage.

The LDCM Observatory shall provide telemetry data to indicate that stored data has been corrected.

The LDCM Observatory shall provide telemetry data to indicate that non-correctable data errors have been detected.

The LDCM Observatory shall use a file based data management scheme.
Rationale: This simplifies data handling and prioritization management in data.

The LDCM Observatory shall have the capability to remove sections of storage by ground command.
Rationale: Needed when warranted by observed or suspected malfunction.

12 Attitude and Orbit Control

12.1 General

The LDCM Observatory shall generate an estimated inertial attitude in the Mean of J2000 frame.

The LDCM Observatory shall be capable of transforming the estimated inertial attitude to a geodetic reference frame.

The LDCM Observatory shall time-tag the inertial attitude estimate with an accuracy of 200 microseconds, 3-sigma.

The LDCM Observatory shall provide inertial attitude knowledge with an accuracy of 24.3 arcsec, 3-sigma per axis, for each image sensor line-of-sight during imaging.

The LDCM Observatory shall provide an estimate of the inertial attitude knowledge at least once per second [TBC].

The LDCM Observatory shall provide stable relative inertial attitude accuracy over a 30 second period of 3.38 arcsec or better, 3-sigma per axis during imaging.

The LDCM Observatory shall provide stable relative inertial attitude accuracy over a 2.5 second period of 1.73 arcsec or better, 3-sigma per axis during imaging.

The LDCM Observatory shall limit the high frequency disturbances applied to image sensor line of sight to no greater than 0.62 arcsec, 3-sigma per axis for frequencies greater than 1.0 Hz during imaging.

The LDCM Observatory pointing reference shall be with respect to the Local Vertical / Local Horizontal reference frame.

The LDCM Observatory shall have a pointing control error less than 108 arcsec, 3-sigma per axis during imaging periods.

The LDCM Observatory shall have a pointing rate error less than 30 arcsec / sec, 3-sigma per axis during imaging periods.

The LDCM Observatory shall be capable of continuous operations in the normal Earth pointing attitude for a minimum of 16 days.

12.2 Maneuvers

The LDCM Observatory shall be capable of performing drag makeup maneuvers.

The LDCM Observatory shall be capable of performing inclination change maneuvers.

The LDCM Observatory shall be capable of performing retrograde propulsion maneuver during the design life of the observatory and still be able to meet imaging specifications within 1 [TBC] day.

The LDCM Observatory shall be capable of performing calibration maneuvers to any inertial attitude within 30 minutes [TBC].
Rationale: To complete a lunar observation while in total eclipse of the sun.

The LDCM Observatory shall be nadir-pointing within 180 seconds [TBC] before and 180 seconds [TBC] after completing an off-nadir image interval.

The LDCM Observatory shall achieve attitude stability requirements within 120 seconds [TBC] of completing a maneuver.

12.3 Ephemeris

The LDCM Observatory shall generate on-board ephemeris.

The LDCM Observatory shall use the International Atomic Time (TAI) time as the observatory time reference.

The LDCM Observatory shall provide the orbital position and velocity in the WGS84 Earth Centered Earth Fixed coordinate frame.

The LDCM Observatory shall provide an estimate of position and velocity time-tagged to an accuracy of 200.0 microseconds [TBC], 3-sigma or better.

The LDCM Observatory shall provide orbital position accurate to 30 m [TBC] radial, 30 m [TBC] in-track, and 30 m [TBC] cross-track – all values are 3-sigma.

The LDCM Observatory shall provide orbital velocity accurate to 0.06 m/sec [TBC] radial, 0.06 m/sec [TBC] in-track, and 0.06 m/sec [TBC] cross track – all values are 3-sigma.

The LDCM Observatory shall provide the orbital position and velocity once per second [TBC].

The LDCM Observatory shall be capable of receiving an ephemeris update command.

13 Propulsion System

The LDCM Observatory propulsion consumables shall provide for 10 years of operational life time at the operational orbit, assuming a 3 sigma worst case mission environment (atmospheric density, thruster misalignment, thruster efficiency, pressurant loading).

The LDCM Observatory propulsion system shall make the fill and drain valve accessible at all times, even while mated to the Launch Vehicle.

14 Launch Services

14.1 Payload Processing Facility Compatibility

14.2 Launch Site Support

15 SMRD Traceability

16 SSRD Verification Cross Reference Matrix (VCRM)